

## HYDROFORMING USING HIGH PRESSURE PULSATION DURING FLUID INTENSIFICATION CYCLE

### BACKGROUND OF THE INVENTION

[0001] This application claims priority from U.S. Provisional Patent Application 60/520,868 filed November 18, 2003, the entire contents of which is incorporated herein in its entirety.

#### Field of the Invention

[0002] The present invention relates to a method of hydroforming metal components, and more particularly to a method of hydroforming metal components using a high pressure fluid having a pulse applied to the fluid.

#### Description of the Related Art

[0003] Hydroforming methods and processes are known in the art for shaping tubular metal blanks, as well as, metal sheets. A typical hydroforming method used for shaping a tubular metal blank may involve placing a tubular metal blank within a die cavity and introducing high pressure fluid within the interior of the blank causing the blank to expand outwardly to conform to the surface of the die cavity. Such a process is disclosed, for example, in U.S. Patent Nos. 5,953,945 to Horton and 6,092,865 to Jaekel et al, the entire contents of each is incorporated herein by reference thereto, respectively. Hydroforming metal parts may have several advantages over typically used stamping operations to produce shaped metal components. Stamping operations may involve pressing a metal part into a desired shape using a large hydraulic press to form the metal part. However, parts created using such a hydraulic press may have inconsistencies due to the characteristics of the forming operation. For example, metal parts formed using a stamping operation exhibit hardening of various portions of the part, usually at bend points or contours, resulting in material inconsistencies throughout the part. Also, metal parts having complex geometries may not be able to be produced in a single stamping operation due to possible limitations in a stamping process. Therefore, welding and joining operations are often necessary to form a complex part, adding to the total cost of the part.

[0004] The process of hydroforming is capable of better repetition and precision when configuring complex shaped parts. As a result, complex parts can be formed in a single

forming operation without the need for welding or joining processes which can lead to material distortions inherent in the joining processes.

[0005] Hydroforming sheet metal may involve placing a sheet metal blank within a die wherein a pressurized fluid is introduced into the die cavity pressing the sheet metal against the contour of the die to form a shaped part.

[0006] While hydroforming produces parts having complex geometries using both tubular and sheet metal blanks, there may be limitations to a hydroforming process including the thinning of base metal material of the blank during the forming process. Also, hydroformed parts may exhibit wrinkling or local deformations produced on the part during a forming process.

## SUMMARY OF THE INVENTION

[0007] An aspect of the invention relates to a method of hydroforming a metal part that includes placing a part to be formed within a die, closing the die to enclose the part to be formed, introducing a high pressure fluid to an interior of the die for expanding the part against an interior surface of the die, the high pressure fluid having a pulse applied thereto for increasing a material flow of the part within the die during the hydroforming operation.

[0008] An additional aspect of the invention relates to a method of shaping a metal blank that includes placing the metal blank within a die; closing the die to enclose the metal blank; and introducing pressurized fluid with pulsed magnitudes of pressure to an interior of the die to expand the metal blank outwardly against an interior surface of the die.

[0009] Another aspect of the invention relates to a hydroforming assembly comprising a blank positioned in the die assembly; a pressurized fluid within the die assembly to force the blank against a wall of the die assembly to conform the blank with the wall of the die assembly; and a pulse-generating device coupled to the pressurized fluid to provide a pulse to the pressurized fluid to create pulsing magnitudes of pressure of the pressurized fluid against the blank to force the blank against the wall of the die assembly.

[0010] Yet another aspect of the invention is a hydroforming assembly which includes a hydroforming die; a metal blank positioned within said die; and means for pulsing magnitudes of pressure of hydroforming fluid being delivered into the hydroforming die for shaping the metal blank.

[0011] These and other aspects, features, and advantages of this invention will become apparent from the following detailed description when taken in conjunction with the

accompanying drawings, which are a part of this disclosure and which illustrate, by way of example, the principles of this invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying drawings facilitate an understanding of the various embodiments of this invention. In such drawings:

[0013] Figure 1 shows schematically an embodiment of a pulse-generating device utilized by the method according to an embodiment of the present invention; and

[0014] Figure 2 shows schematically an embodiment of a hydroforming system utilizing the pulse generating device in accordance with an embodiment of the subject invention.

### DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0015] Referring to Figure 1, there is shown an embodiment of a pulse-generating device 5 used in a method of hydroforming according to an embodiment of the present invention. In the illustrated embodiment, the device 5 includes a variable frequency drive motor 10. The drive motor 10 includes a rotatable drive shaft 17 that is connected to a connecting rod 20 by a bearing journal 15. Upper and lower bearing journals 19, 21 also rotatably support the drive shaft 17. The connecting rod 20 is pivotally attached to a piston plunger 25, e.g., by a pivot pin 23. The piston 25 is disposed within a cylinder 30 and is sealed within the cylinder 30 by an appropriate piston seal 35. The bearing journal 15 is eccentrically mounted to the drive shaft 17 such that rotation of the drive shaft 17 causes linear movement of the connecting rod 20. The linear movement of the connecting rod 20 cause corresponding linear movement of the piston 25 within the cylinder 30, which displaces fluid to create a frequency or pulse. The cylinder 30 is connected to a fluid line 40, e.g., a pipe, via an outlet port 45. The fluid line 40 introduces the pressurized fluid into a forming die to create a formed metal part. The pulse or wave is generated by the variable frequency drive motor 10 connected to the cam operated piston 25. The variable frequency drive motor 10 may be coupled to the piston 25 in any other suitable manner.

[0016] In a preferred aspect of the present invention, the variable frequency drive motor 10 has a frequency range of from 5 to 60 hertz. The frequency range of from 5 to 60 hertz results in a frequency fluid volume displacement in the range of from .001 to 5 liters of

water. The piston 25 amplitude preferably has a range of from 1 to 50 mm resulting in a pressure amplitude in the range of from 5 to 500 bar. The frequency pressure range preferably, is from 5 to 1500 bar with a frequency duration of preferably 30 seconds. Through put speeds for parts formed by the hydroforming operation preferably are in the range of from 5 to 60 seconds.

[0017] As noted above, tubular structures as well as sheet materials may be utilized as blank materials for the hydroforming operation of the present invention.

[0018] While a preferred device is shown in Figure 1 for introducing the pulse into the hydroforming fluid, other methods or devices may be utilized by the present invention. For example, valves associated with the fluid line 40 leading to the forming die used in the hydroforming operation can be manipulated or oscillated; thereby introducing a frequency or pulse to the hydroforming fluid, preferably in the range of the characteristics outlined above with respect to the preferred embodiment.

[0019] The method according to an embodiment of the present invention includes placing a part to be formed within a hydroforming die, closing the die, and then introducing a high pressure fluid to an interior of the die, the high pressure fluid having a pulse applied thereto. The high pressure fluid expands the part against an interior surface of the die resulting in a formed metal part. As the high pressure fluid is introduced to the die generally, the metal part begins expanding against the die surface. Generally in a conventional hydroforming operation, a static pressure of from 300 to 500 bar is utilized to expand the metal against the die surface. The conventional hydroforming operation or method, as stated above uses a constant or static pressure resulting in a constant expansion of the metal against the surface of a die.

[0020] The method according to an embodiment of the present invention utilizes a wave or pulse flow of pressure; thereby increasing the material flow in the cavity or die by not constantly expanding the metal blank, resulting in a more consistent wall thickness, especially in portions of a part having a complex curvature that would often see thinning when a constant pressure hydroforming fluid is applied to the die.

[0021] Figure 2 is a cross sectional view of one type of hydroforming die assembly for illustrating the method of the present invention. Of course, the shape of the die cavity illustrated in Fig. 2 is particularly adapted to the shape of a tubular part. Fig. 2 is representative in nature and illustrates two hydroforming ram assemblies 500 and 502, which have outer ram members, respectively, which are movable to engage and seal opposite ends of a tubular blank 510, which has been bent (for example in a CNC bending machine) to fit

within a die cavity 512 of a hydroforming die structure 514. The blank 510, which is in the form of a tubular metallic wall merely illustrates one example, but is illustrated to represent any U-shaped or inverted U-shaped metallic wall or blank member. The tube 510 is preferably immersed in a water bath so as to be filled with hydroforming fluid. The rams 500 and 502 include hydraulic intensifiers, which can intensify the hydroforming fluid to expand the tubular wall or blank into irregularly outwardly deformed conformity with the die surfaces so as to fix the tubular wall or blank into a predetermined irregular exterior surface configuration. The outer rams 504 and 506 push inwardly into the die structure so as to create metal flow within the blank 510 so as to replenish or maintain the wall thickness of final tube part within about  $\pm$  of the original wall thickness of the blank (i.e., to compensate for wall thinning during diametric expansion of the tube). As described above, the device 5 is employed in the embodiment of Fig. 2 to introduce a frequency or pulse to the hydraulic fluid being pressurized by rams 500 and 502. The device is only illustrated in connection with only one input at ram 504, but could be provided to multiple inputs, for example, to both rams 504 and 506. Also, although illustrated as entering ram 504, entrance of the pulse or frequency to the hydraulic fluid can occur at various locations in a hydroforming system. As a result of the introduction of the pulse to the hydraulic fluid, the flow of material is improved to ensure that the wall thickness does not become too thin and to prevent the formation of wrinkles, especially at bend areas.

[0022] Many modification and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced other than as specifically described.